Managing natural resources using GIS: Experiences in India

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Abstract

GIS technology is considered an exciting tool in the context of governmental planning systems for natural resource management in developing countries. However, despite rhetoric to the contrary, its impact has been of little value to national processes of development. The Indian government seems to be in the process of making long-term commitments to using GIS for natural resource management. National initiatives are being conceptualised and implemented by different organisations. They involve huge outlays of resources and have the potential to initiate large scale changes in district administration. For these changes to be productive, it is important that these initiatives are carefully planned. Here, we discuss four technological and management implications for the management of natural resources using GIS based on our past experience of district-level computerisation. © 1997 Elsevier Science B.V.

Keywords: Geographic Information Systems (GIS); Development planning; India

1. Introduction

Geographic Information Systems (GIS) are considered an exciting tool for promoting socio-economic growth [17]. While there have been many forms of mapping systems available since the 1960s, GIS technology has evolved since the early 1980s. The potential of this technology to provide planners with up-to-date, reliable information about the environment and its characteristics and its relation to a region's inhabitants has prompted governments to undertake large-scale initiatives involving high investment in order to implement this technology. For example, Fletcher et al. [4] have described GIS as the technology that has had the largest impact on the thinking of managers in county departments in the United States. In the UK, Campbell and Masser [1] suggest that nearly 70 percent of local government organisations have either purchased GIS technology or were planning to do so in the near future.

Since the late 1980s, this technology has become increasingly visible in developing countries [17, 19]. In terms of the development planning function, there has been a shift towards spatial based eco-development planning and towards the creation of district profiles of natural resources and socio-economic data. This trend, coupled with an increasing awareness of the importance of GIS technology in the planning process, has provided the impetus to various government agencies to initiate large-scale GIS programmes. While these initiatives are in the early stages, and have not really become operational, we feel quite strongly that these efforts are worth reporting because of the important influence of the initiation stage of technol-
ogy implementation on subsequent project outcomes. March and Sproull [11] write that during the initiation stage, management tends to establish a criterion for according legitimacy to a new technological order, a criteria which also underlies subsequent developments in the project. Similarly, Tyre and Orlikowski [18] say that the initiation stage of the technology provides ‘windows of opportunities’ for creating change. They argue that once that window is lost, bringing about change becomes more difficult. Sieber [16] points out that investment in GIS presents economic risks because they are typically large systems involving huge financial outlays, especially during the initial stages of implementation, where long-term, irrevocable commitments must be made. Expenses incurred in developing base maps, for example, may reach $1.25 million annually, and may be incurred for as many as five years. The involvement of multiple stakeholders, each with their individual missions and data needs, often exacerbates these economic risks, especially in government settings. Individual agencies may seek to develop a GIS on their own, resulting in databases that duplicate data possessed by other agencies. Thus, an important aspect of the implementation problem is the coordination of the initial data sharing effort in terms of its cost, technical requirements, and other organisational and political considerations [14].

One country that has recently made large-scale investments in the use of GIS technology for development planning is India. These investments come after almost a decade of experimentation with computer-based information systems. This experimentation was as a result of inadequacies in the previous manual system of development planning and monitoring which in turn stemmed from the fact that there was no real locally-relevant, integrated approach to development planning [5]. While numerous individual programmes had been established by the central government, local administrators had little or no role to play in their planning and administration. In 1987, the central government, committed to a policy of modernisation and technology drive, decided to promote the use of computers at the local level with the aim of integrating development planning. However, rather than consolidating efforts, various individual ministries launched projects to serve their own administrative and planning functions without providing adequate support. Moreover, these systems had been designed and developed in a top-down fashion without adequate consultation with state government and local personnel, who were the users of the system [9, 10]. Over the years, these problems have led to non-use of centrally-designed information systems and the promotion of end-user computing applications in districts. Computers increasingly began to be used to automate routine tasks believed by local administrators to be useful for them, such as monthly progress reports and annual action plans. With the increase in computer usage, individual districts began to introduce their own mechanisms for providing local technical and human resources support.

Since 1993, in addition to routine automation tasks, there has been considerable self-learning by local administrators. As a result, some districts have begun using the computer for more analytical applications to assist the local planners and for ensuring that development programmes are targeted where they are most needed. For example, the sorting of rural poor household by income level, caste, and occupation. A more complex type of analysis, currently being undertaken in Gujarat state, is to improve the effectiveness of the Integrated Rural Development Programme. The system involves the generation of a data set of rural poor households according to locally-relevant criteria. More recently, local level planning has taken on an additional dimension – that of ecological and environmental development. The Secretary, Department of Space is quoted as saying that “the economics of development must expand within eco-systems which have limited regenerative capacities. The need is for a full integration of environmental and developmental issues for decision-making…” [8]. This additional focus is providing the impetus for the Indian government to shift their emphasis from planning based on non-spatial or individual/household parameters to one based on space and area, often referred to as ‘geomatics.’ It is intended that individual districts in India will develop strategies that make efficient use of resources to maintain the ecological system and to provide people living there with their socio-economic needs. However, if these efforts are not adequately coordinated, there could be mammoth duplication of resources and systems without operational value.

The focus of this paper is to review some of these GIS initiatives taking place, especially with respect to
their initial conceptualisation and design, and to critically examine some of the problems and opportunities that planners are faced with in trying to make these initiatives effective. In the next section we review four initiatives taking place for natural resource management. In section three, we critically examine the progress of these projects, focusing on the problems and opportunities that are presented to the planners. We discuss implications for the successful utilisation of GIS technology for development planning by drawing upon our understanding of the historical context of computerisation within Indian district administration.

2. Current status of GIS in India

There is increasing recognition that no development programmes can be economically and socially viable unless natural biological systems are preserved. In the Indian context, a number of national agencies are in the process of implementing GIS projects, mostly oriented towards ecological development at district levels. An example of this emphasis is in land management. 'Wastelands' refers to degraded land comprising more than 25 percent of the total area of India – this is a high priority area in national development. The Planning Commission of India has recognised GIS as "an invaluable planning tool in land use and wastelands development... for identifying treatment areas and models, making trade-off calculations in choosing from competing land uses, and carrying out simulations and impact assessments... [12]."

Since the late 1980s, a number of similar GIS projects have been initiated. In addition, other agencies are playing facilitating roles, for example, the Survey of India is establishing the digital cartographic database for the country, and the National Remote Sensing Agency is collecting and disseminating satellite imagery. Other government agencies are using GIS to address domain specific applications – for example, the forest wing of the MOEF, The Census Department, Geological Survey of India, Town and Country Planning Organization, Bombay Metropolitan Development Authority, Wildlife Institute of India, and the Coast Guards. A few private sector firms like Hindustan Lever are using GIS as a tool for decision support. Recently, a national Geomatics society was established to provide professionals interested in the issue of spatial location with a common platform for interaction.

2.1. National Informatics Centre (NIC)

While the NIC has been working with computerisation since the mid-1980s, their GIS initiative started in the early 1990s. The primary impetus was 'the emergence of the GIS of NIC (GISNIC) and the establishment of NICNET (high-speed telecommunications network) facilities at the district level [7].' Starting in 1987, the NIC established offices in all 500 districts in 32 states/union territories. Each district office has two NIC officers and is equipped with a PC 386, dot-matrix printer, and applications software. The district, state, and central government offices are interconnected through NICNET. The Director General, NIC, during the recent Geomatics: Vision 2000 conference held in Delhi reported that the NICNET information highway with speeds of up to 2.2 Mbps per node was in position in 15 cities and expected it to be expanded by 1995 to 70 cities [15]. Also, by 1997, the NICNET was expected to be expanded to 6000 development blocks at sub-district level and an in-house developed GIS package was to be installed in various pilot districts.

An independent GIS division was established in the NIC office in 1992 and its current focus is to upgrade the first version of their in-house GIS software. The second version, developed on a Unix platform, is currently in the Beta testing stage and expected to be released to various district offices over the network. Nodal centres of GIS expertise are to be located at the state HQs. The GIS group leader described their development efforts to be taking place on a 'mission mode' with relatively little pressure to produce short term project deliverables.

Initially, the NIC selected a few pilot districts where software could be used for the generation of thematic maps. In the next stage, software and hardware upgradations will take place. Some preliminary training efforts have been initiated and some staff have been trained. Another feature of the NIC activities has been the initiation of the Natural Resources Informatics Programme (NRIP). Sustainable development is only possible by preventing ecological and environment degradation. This requires the reorientation of plan-
ning towards natural resources utilization, using decision support technologies locally [2]. The NIC aims to establish comprehensive socio-economic cum natural resources databases for each village or cluster of villages, and to include extensive data on sectors such as geology, land use, land cover and water resources. The NIC has established a pilot site in Aligarh district of Uttar Pradesh in collaboration with the regional centre for remote sensing that is located within a local university.

2.2. **Department of Science and Technology (DST)**

The Natural Resources Data Management System (NRDMS) started to develop natural resources profiles of different regions in 1986. An important aspect of the effort is the development of a PC-based GIS software called GRAMS to support the management of natural resources. The vision for the NRDMS programme is primarily that of an R & D effort. Unlike the NIC effort which is targeting all districts in the country, the DST is working on a smaller scale in some 12 or 13 areas which correspond to the different agro-climatic zones in India. Typically, a DST district centre is located in a local engineering college and manned by two or three DST staff who are stationed there. A district level committee is responsible for developing the GIS applications. The state contributes 25–30 percent of the project cost.

In the early 1990s, the DST felt that they had to demonstrate viability by establishing centres in every district of one state. Karnataka state put forth a proposal to implement this concept. Under this plan, natural resources databases are now being developed and implemented in each centre for both graphic and attribute data. The structure of the databases was designed at the central office in Delhi. However, the design is being adapted at the local level in keeping with data management methods at each district. Eight sectors have been selected, including natural resources, infrastructure, ground water (water resources), and other socio-economic aspects. The databases in most cases are being implemented on a PC 386 platform using in-house developed GRAMS software.

In Karnataka, the office of the Zilla Parishad (ZP) is responsible for overall district planning. As of summer 1995, 10 centres have been established out of a total of 19 districts in the state – six are at academic institutions and the rest in the ZP offices. Presently, the DST has placed two technical people, normally engineers with computer background in each centre, often with Ph.D. degrees in Geology. The DST staff are involved in setting up the centre and then will be responsible for its subsequent operations for five years. It is hoped that this local DST staff will be absorbed by the state government after five years.

There have been many problems related to data management. The primary problem in the whole process has been the lengthy compilation of data. As a result, the DST is often only dealing with secondary data sources, that is data which is already available. However, there are various problems with these sources because the data in government departments are not compatible with formats prescribed by the DST in their development guidelines. However, the DST have shown flexibility at the field level, and they are in some cases collecting data in whatever format is available and then converting it to the required format. In other cases, they are trying to use their system to initiate changes in data management practices. Another related problem is that of manpower. The database development task is people-intensive, but in most cases the line departments cannot release one of their people to work exclusively on this job.

2.3. **Department of Space (DOS)**

The India government has emphasised the development of a strong space programme through the DOS. Since the late 1970s, various programmes of the DOS used remote sensing for natural resources surveys – for example, to be used in forest resources [20]. Through the establishment of a multi-spectral data analysis system and a data receiving station at National Remote Sensing Agency, Hyderabad and the work of a data centre for satellite images, it has become possible to use remote sensing data for project management at an operational scale.

Advances in remote sensing technology are expected to provide a primary source of data. Presently, IRS-1A and 1B satellites are providing data with about 36 metres resolution. While this provides the capability to map natural resources at about 1 : 50,000 scale, it does pose limitations when assessments have to be done at the village level. The second
generation remote sensing satellites IRS-1C and 1D are expected to provide 10 metre resolution data.

The DOS has defined the National Natural Resource Management System (NNRMS) for utilising socio-economic and other conventional surveys [6], including, for example, forestry, agriculture, drought monitoring assessment, and wasteland mapping. A number of these projects include the task of integrating remotely sensed data with other non-spatial data for resources management. An example of such a project is a Regional Information System for Bharatpur district in Rajasthan. Another focus of the DOS initiative is the development of GIS software. Users have collaborated with two software industry partners under Technology Transfer agreements to develop two packages. ISROGIS, is based on the PM-Quadtree structure, while GEOSPACE is a raster-based software. Both have been installed in user-agencies on a variety of platforms and operating environments.

2.4. The Ministry of Environment and Forests (MOEF)

The management of ‘wastelands’ is a priority area in the context of national development. In 1991, the MOEF embarked upon an ambitious project to apply GIS technology for wasteland management. This was based on prior work carried out in 1986 when the DOS under the National Wasteland Identification Project developed detailed wasteland maps of 147 districts in the country on a 1 : 50,000 scale. A second factor was the funding by the United States Agency for International Development (USAID) of a project to initiate GIS technology in India through training and workshops.

Eight scientific institutions were allocated to parts of the country that had a large area of degraded land. USAID played a significant role in the initiation of the project by supporting the trip of the hardware selection team to the United States, by donating GIS packages, by helping to conduct two training workshops, and by providing funds to the extent of US $0.25 million which started the project. The National Afforestation and Ecology Board acted as the link pin in the project, being responsible for the functions of coordination, communication, budgeting, and hardware/software acquisition. The eight scientific institutions were the primary units for demonstrating the effectiveness of GIS technology, and then transferring the technology and methodology to the district administration. The district administrators at the local level were the potential users of the system.

Four different brands of GIS software were used in the project, including five copies of Arc/Info and one each of the other three packages. Three of the four Arc/Info packages were on workstation platforms, and all the other systems were on PC environments. The institutions experimented with different methodologies in the formulation and implementation of the projects. For example, while most institutions worked at a 1 : 50,000 scale, some others also worked at the cadastral level of 1 : 10,000. Some institutions adopted a watershed as the unit of analysis, while others used a village.

By early 1994, five of the eight institutions had submitted proposals for continuation of the projects. Sanctions were obtained for these proposals from the Secretary in March 1994 to start the continuation phase which concluded in March 1996. A workshop was organised in July 1995 to review the progress of the five projects which had gone ahead with the continuation phase. The participants in this workshop included the scientific institutions which participated in the MOEF project, ourselves, and other government officials who are involved in undertaking other GIS initiatives in the country. In three of the sites, it was seen that there was negligible progress in getting the systems transferred to the users, and in integrating the technology with ongoing work processes in the district. However, in two of the sites it was felt that a basis had been established which could potentially enable larger-scale GIS use in the future. It was felt that this ‘success’ seemed to have come about more through the efforts of individual project leaders rather than institutional mechanisms.

The main characteristics of the national GIS initiatives in India are summarised in Table 1.

3. An analysis of the national GIS initiatives: Problems and opportunities for GIS project managers

Broadly, three categories of GIS players are visible on the national scene: developers, users, and facilitators. Presently, the users category is primarily organisations such as the Census department and the
Table 1
An overview of the national GIS initiatives in India

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>NIC (NRIP)</td>
<td>Focus on establishing technical infrastructure</td>
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<td></td>
<td>Pilot centres established in selected districts</td>
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<tr>
<td></td>
<td>Plan to develop natural resources information system around GIS core in selected districts</td>
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<tr>
<td>DST (NRDMS)</td>
<td>Focus on R&amp;D exercises involving the development of natural resource data management systems</td>
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<tr>
<td></td>
<td>R&amp;D projects in various districts in Karnataka state</td>
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<td></td>
<td>Projects being implemented in collaboration with local technical institutions</td>
</tr>
<tr>
<td></td>
<td>Plan to transfer technology to district offices at end of R&amp;D phase</td>
</tr>
<tr>
<td>DOS (NNRMS)</td>
<td>Operationalisation of remote sensing programmes</td>
</tr>
<tr>
<td></td>
<td>Focus on development of GIS software for commercial usage</td>
</tr>
<tr>
<td></td>
<td>GIS identified as a tool for establishing sustainable development practices using an integrated approach</td>
</tr>
<tr>
<td>MOEF</td>
<td>Focus on establishing and testing a methodology for wasteland management</td>
</tr>
<tr>
<td></td>
<td>GIS project implemented in collaboration with leading science &amp; technology institutes in the country</td>
</tr>
<tr>
<td></td>
<td>Technical feasibility of GIS successfully established</td>
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<tr>
<td></td>
<td>Only marginal progress made in establishing organisational feasibility of GIS systems</td>
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Geological Survey of India. However, the district administration is expected to become a very significant user in future. The primary focus of most of the initiatives has been largely technical. However, as these initiatives progress from the technology development phase to the next phase, where the objective is to actually have relevant authorities apply the technology to specific problems, social aspects assume central significance.

3.1. Institutional reforms

One major constraint to the earlier computerisation efforts was the paternalistic style of authority in the administration. The introduction of computerisation threatened to replace authority based on hierarchy with that based on expertise. The district was constrained in terms of norms from the centre, for example, in terms of how beneficiaries were selected for government assistance. These rigidities tended to stifle micro-planning efforts which require local initiative and judgement in interpreting output related to individual households, schemes, village infrastructure and resources. Increased flexibility is necessary to allow local authorities to tackle more relevant problems in more appropriate ways.

Also the process of development and utilization of GIS is complex and takes a long time. Thus, it is important to maintain continuity by developing an effective and sustainable partnership between the technology developers, users, and facilitators. For example, in the DST initiative, financial commitment was obtained by the state government of Karnataka. In contrast, there are examples of GIS initiatives launched in developing countries and funded by aid agencies which run into major difficulties when the funds are allocated elsewhere and when alternative systems are funded by different agencies [3].

Another issue deals with the need for having greater integration between the different GIS initiatives. While independent bottom-up efforts engage users by fostering motivation, creativity, and multi-faceted learning experiences, such efforts can also involve duplication. Hence, a top-down strategy is needed.

3.2. Technological transitions

Technological transitions reflect the process by which organisational systems change from a certain way of doing work to other ways. When new technology is interpreted as a continuation of existing technological capabilities, the transition becomes smoother as compared to the case where the change is seen to be a radical departure from existing capabilities [14]. Continuities of technology build upon an established base of knowledge whereas discontinuities require the creation of new knowledge before the transition can occur. In the context of using GIS for Indian district administration, we are talking about a
potentially discontinuous change involving a move to a predominantly map-based planning system supported by GIS from an existing largely non-map based system that is becoming increasingly computer supported.

Building awareness about GIS is fundamental in enabling smoother transitions. Planners are often unaware of new technology. The task of awareness building can be approached in different ways. First, by providing planners with demonstrations of working GIS applications. Second, by providing exposure to earlier forms of mapping systems such as CAD and Computer Vision that can also contribute to making smoother transitions because they introduce the user to the concept of spatial representation. Third, by monitoring the social interactions between users and developers. Feedback from users is not systematically recorded. However, such data could help to develop awareness and a sense of continuity with past events. This is especially important in the context of district administration where frequent transfers of local staff are seen as impeding progress.

Another important aspect of the transition to GIS relates to the system of data management. It is extremely important to compile GIS databases that are relevant to the problem of micro-level planning and also which are compatible with existing systems such that the costs and the effort of change are marginal. This requires the development of data management strategies which includes the articulation of a vision of data needs, the establishment of mechanisms to physically create the systems, and the definition of data responsibility – for example, by identifying the custodian of data.

3.3. Human resources development (HRD)

Another bottleneck with past computerisation efforts has been the limited demand for analysis by district officials. The task of planning has been viewed primarily as an impersonal and mechanical exercise. Also, departments recruit novice users with a limited understanding of technology for their work. There was also the problem of qualified people being unwilling to work in remote district offices. Given past experience with the extent and nature of HRD problems in computerisation, it is important to address issues related to manpower very seriously.

Strategies for HRD in GIS will need to be tailored towards the awareness and capability of local administrators as well as towards the state of maturity of GIS usage in the district. There are two forms of knowledge – conceptual and operational. Conceptual knowledge reflects the capability people have in thinking in spatial terms rather than in detailed software procedures, and involves developing understanding of geographical concepts related to topology, georeferencing and geo-coding. This will allow the user to visualise problems in spatial terms and translate his/her need for geographical products into workable GIS solutions. Operational knowledge relates to the procedural aspects of GIS – for example, how digitizing is performed, how data is entered into the database, or how reports are generated. For the senior level district officials, conceptual knowledge is more relevant, as it will provide the capability to articulate a vision for GIS use in their departments. Then, to translate these visions into workable applications, people are required at lower levels with operational knowledge.

3.4. Technical support

Poor technical support was identified as a key factor in the failure of earlier computerised systems. The main cause for this was the physical separation of the District Rural Development Agencies and the NIC offices and the fact that some districts were remotely located thus creating delays in obtaining support. An absence of local capability to deal with technical problems set up the need to obtain support from the centre: this led to delays. In terms of GIS, the issue of technical support needs to be considered with great care because the technology is relatively new and complex.

The GIS developers are either government organisations, such as DST, DOS, or NIC, or private sector distributors of foreign companies. While the government organisations do not have the adequate infrastructure to provide technical support, the private sector distributors are often sales-oriented and do not give adequate importance to the issue of long-term support. For example, in the NAEB-sponsored GIS initiative, it was seen that vendor-related problems led to major delays in project implementation. The DST and the DOS are trying to outsource the marketing and support function to a private organization.
The issue of support becomes more crucial as the systems are established in remote district locations, which are harder to access, experience greater shortages of equipment and manpower resources, and have poor operating conditions. For example, frequent power failures may require the system to be constantly re-booted. Addressing the issue of technical support has to be considered carefully at all levels. The measures at the user level includes a careful definition of hardware/software requirements, ensuring selection of appropriate software, and drawing up sensible support contracts with vendors. Firm support contracts between the user and the vendor can safeguard the interests of both parties. For example, in the maintenance contract in the districts, there is a financial penalty clause for every day the vendor delays in responding to a reported technical fault. The NIC staff feel that this had greatly contributed to improved vendor support.

3.5. Summary

As Zuboff [21] and Peterson [13] state, the full benefits of GIS technology will not be achieved when it is merely applied to automating manual operations, but only when it provides additional information about the nature of district administration which will enable authorities to introduce new work practices. It is a tool which can provide additional insights into the task of development planning by enabling planners to have a visual representation about the impact of development programmes over time. This additional insight may force changes in accountability. For example, a local politician or administrator may tell villagers that he (she) intends to commit resources towards developing new roads in the district. However, a map of that area may subsequently reveal that no road was built.

4. Conclusions

The experience of district level computerisation in India provides both opportunities and challenges for the implementation of GIS technology. A valuable opportunity exists to learn from the successes and failures of the last eight years. An important learning from the past has been that providing flexibility to local administrators to direct technology to their local needs has contributed significantly to the usage of computers. Providing this flexibility to administrative practices is both a challenging and complex task. While a broad vision about the role of technology needs to be articulated at higher levels in the administration, adequate flexibility has to be provided to the users at the level of the district to be able to apply GIS effectively for locally relevant problems.

References


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